

The Effects of Interactive Stratospheric Chemistry on Antarctic and Southern Ocean Climate Change in an AOGCM

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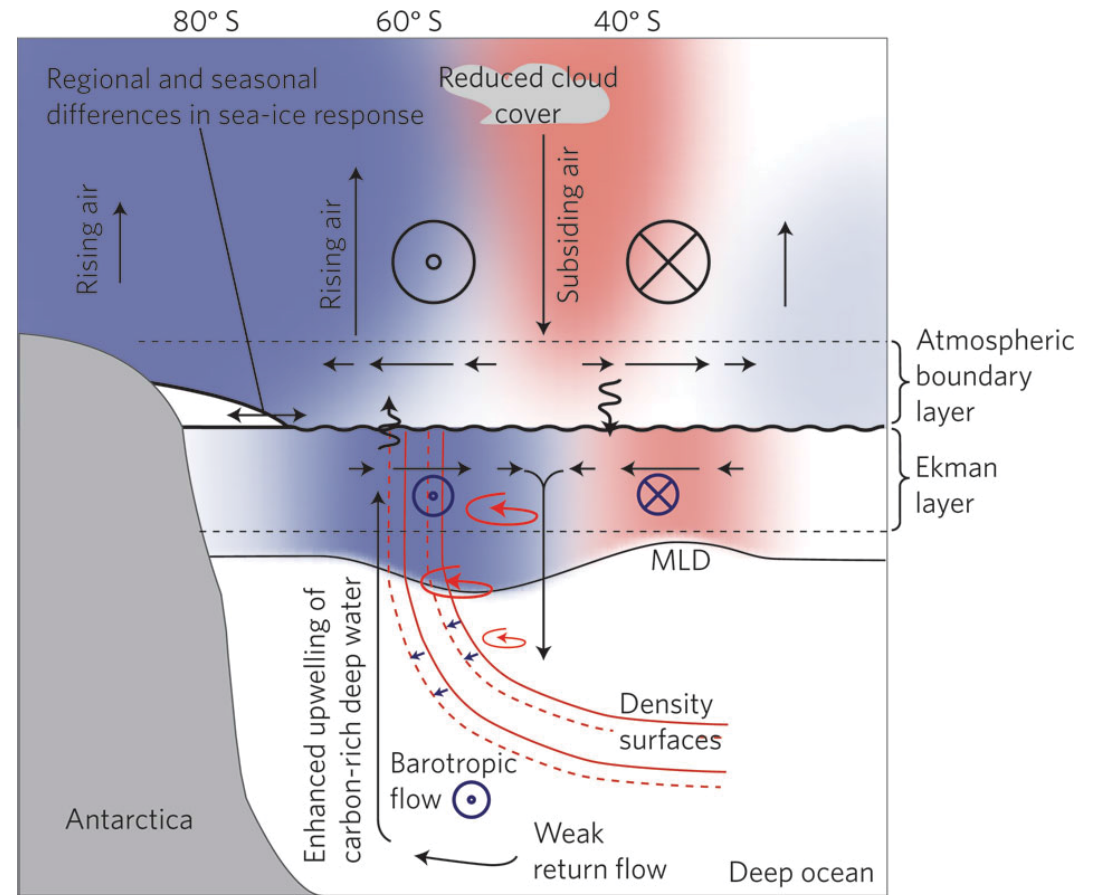
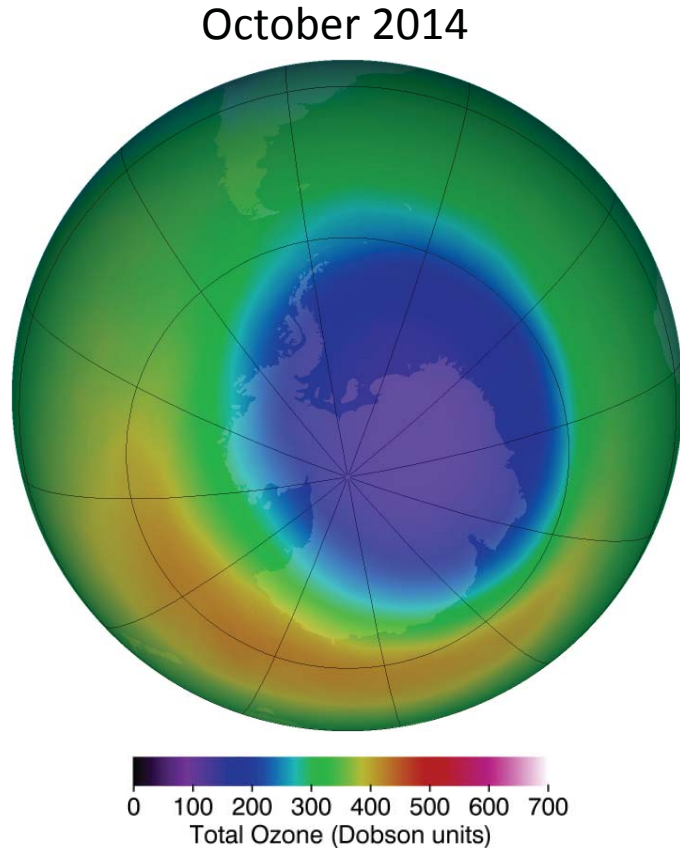
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Antarctic Ozone Hole is the Main Driver of SH Climate Change

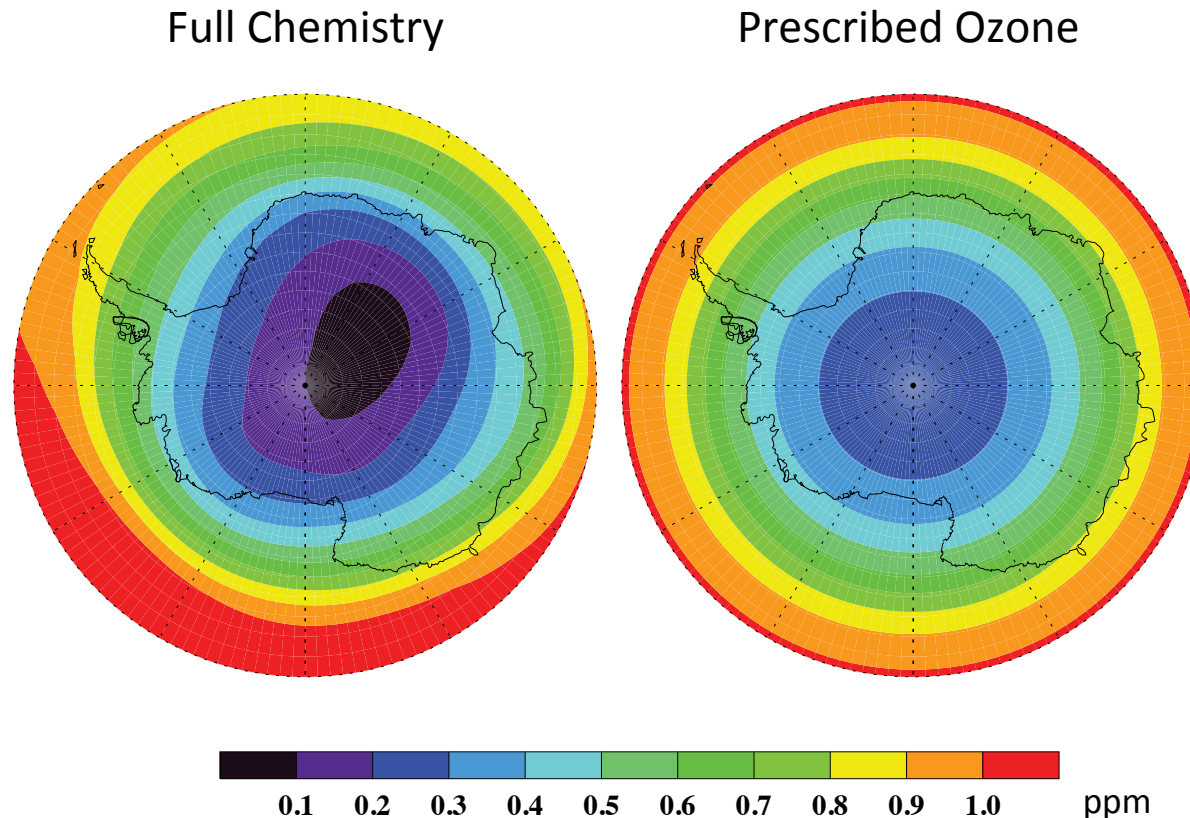


Surface fluxes, Ekman transport and MLD changes act in concert to produce SST response. Eddy heat fluxes act in the opposite sense.

- ⊙ Increased eastward wind/current
- ⊗ Increased westward wind/current
- ↑ Heat fluxes
- ↻ Eddy response

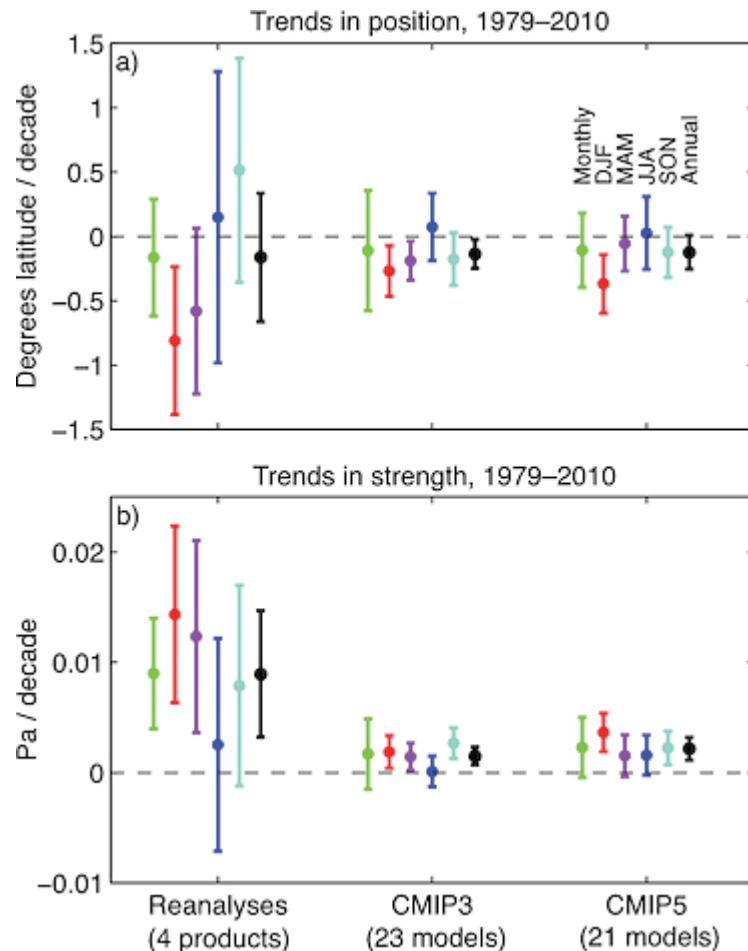
Thompson et al., Nature Geoscience, 2011

Known Issues of Simulations with Prescribed Ozone



- **Prescribed ozone lacks zonal asymmetries.**
- **Prescribed ozone underestimates Antarctic ozone depletion.**
- Prescribed ozone does not have the diurnal cycle of the mesospheric ozone

CMIP Models Underestimate Poleward Shift and Intensification of SH Westerlies



- Poleward shift and intensification of the SH westerlies has important implications for the Southern Ocean circulation.
- CMIP models significantly underestimate the strengthening of the surface westerly wind-stress.

Motivations

1. Can we improve the modeled SH wind-stress change by using interactive stratospheric chemistry?
2. What are the impacts of interactive chemistry on simulations of Southern Ocean circulation change?

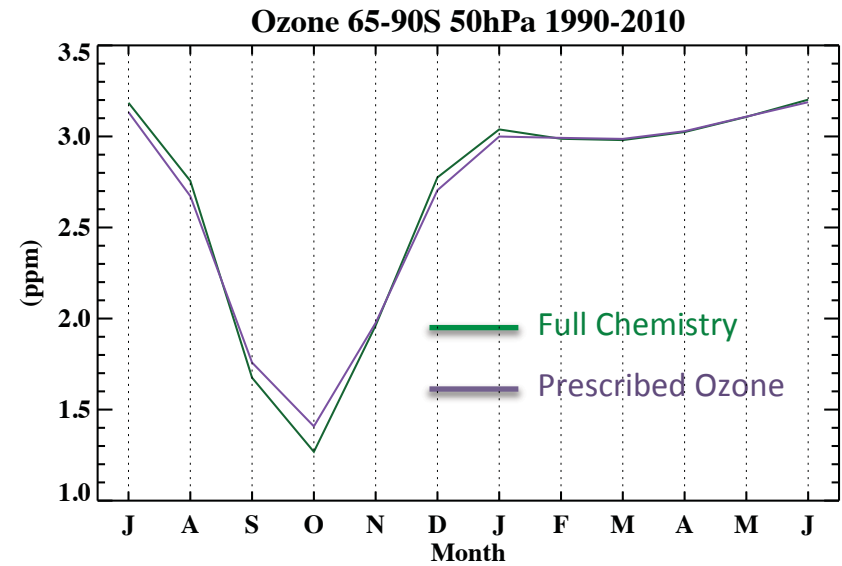
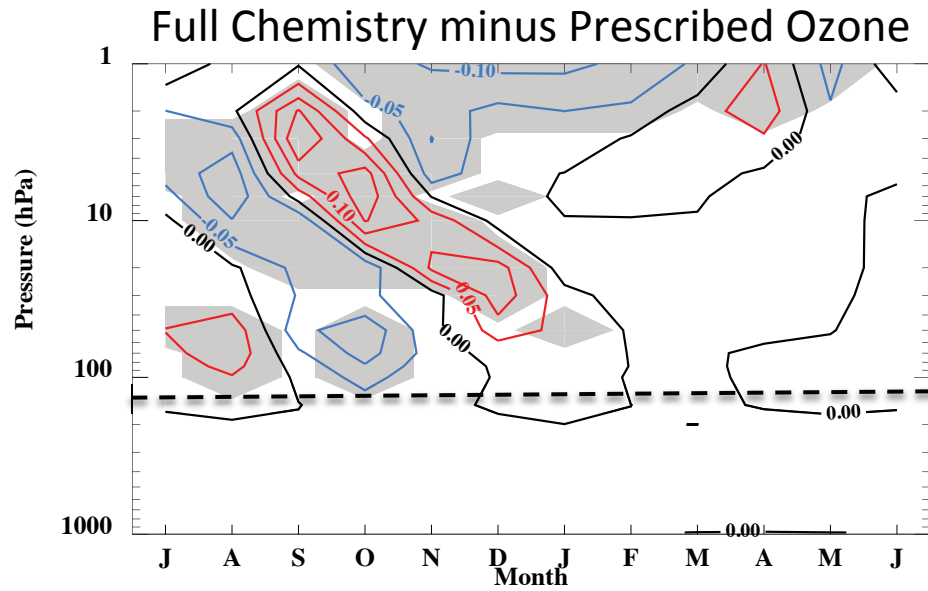
GEOS-5

- Goddard Earth Observing System, Version 5 (GEOS-5)
- Coupled ocean version, Modular Ocean Model (MOM4) and LANL CICE sea ice model
- Atmosphere model resolution: $2.5^{\circ} \times 2^{\circ}$, 72 levels, 0.01hPa model top
- Ocean model resolution: 360X200, 50 levels
- Two methods to represent stratospheric ozone:
 - (1) **AOCCM**: Interactive stratospheric chemistry
 - (2) **AOGCM**: Prescribed monthly and zonal-mean ozone

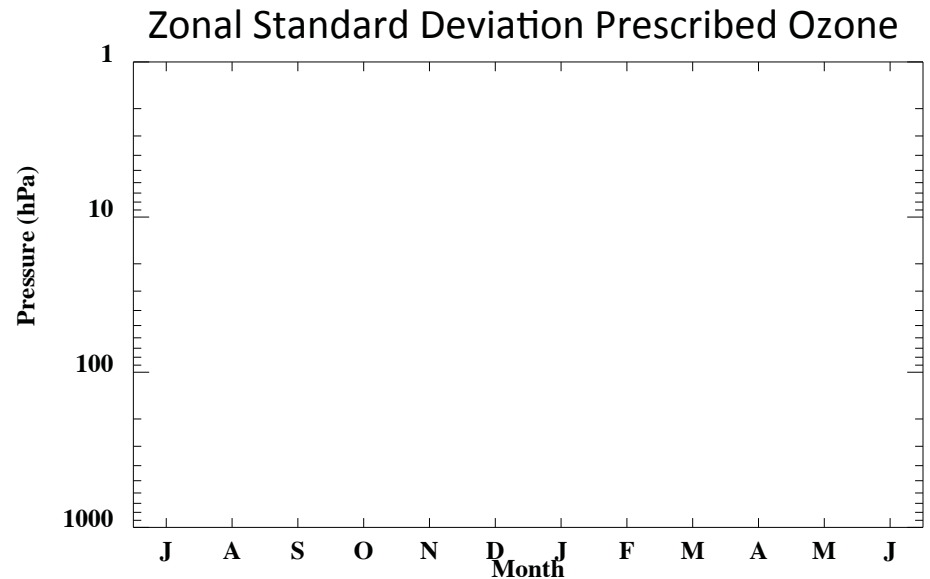
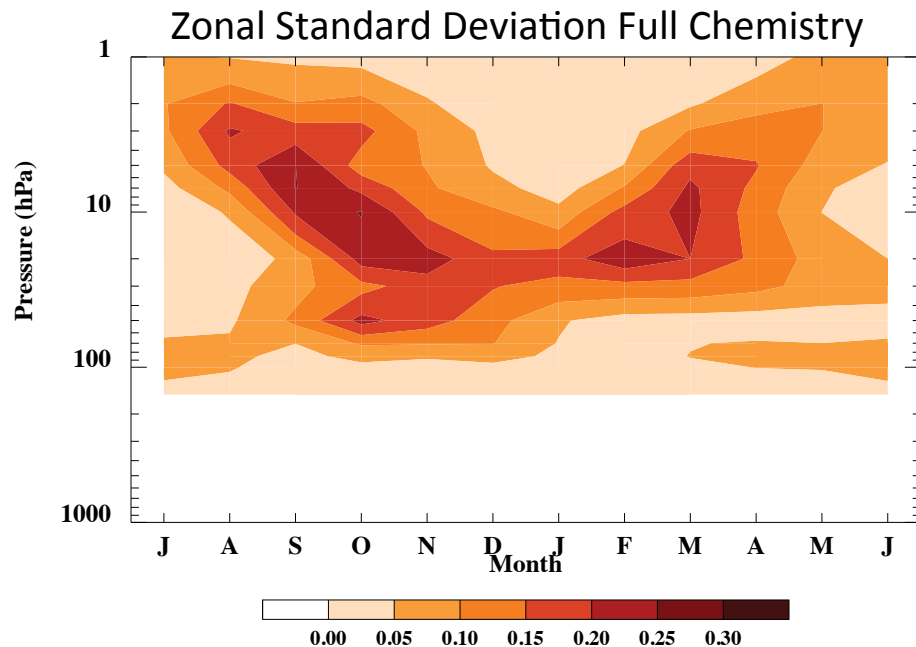
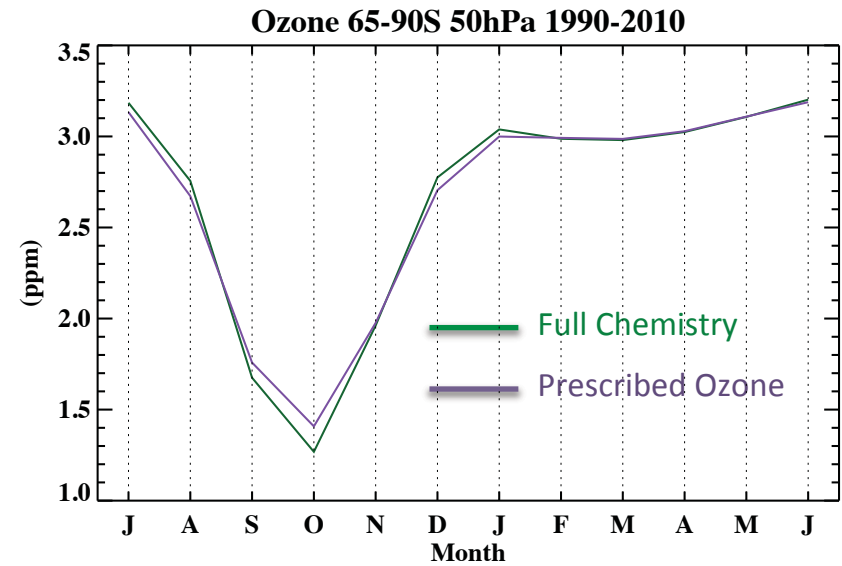
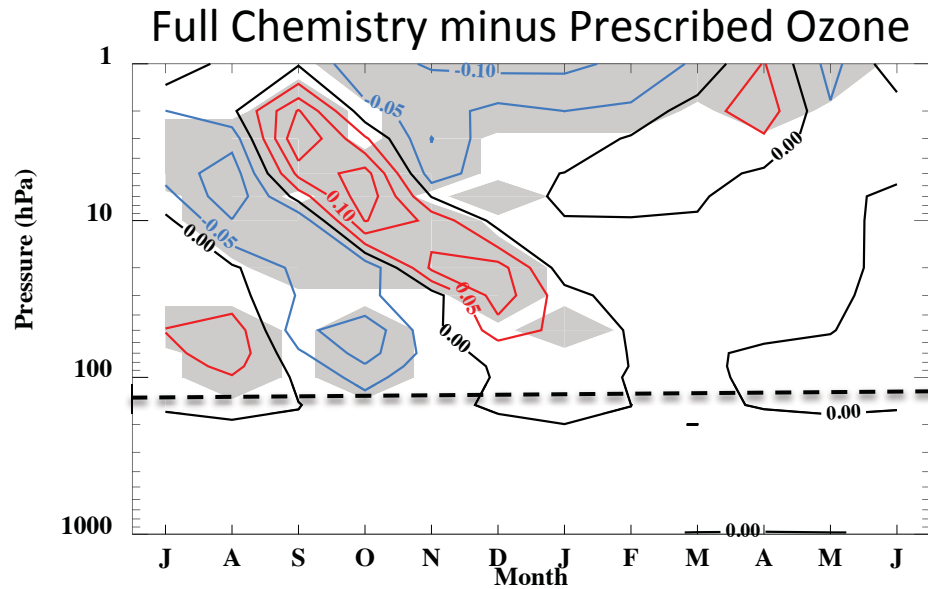
Experiment Design

- A pair of ensemble transient simulations 1960-2010: one with interactive chemistry, and the other with prescribed ozone
- The prescribed ozone simulations use outputs from the interactive chemistry simulations
- 4 members for each ensemble

Prescribed ozone underestimates ozone depletion forcing

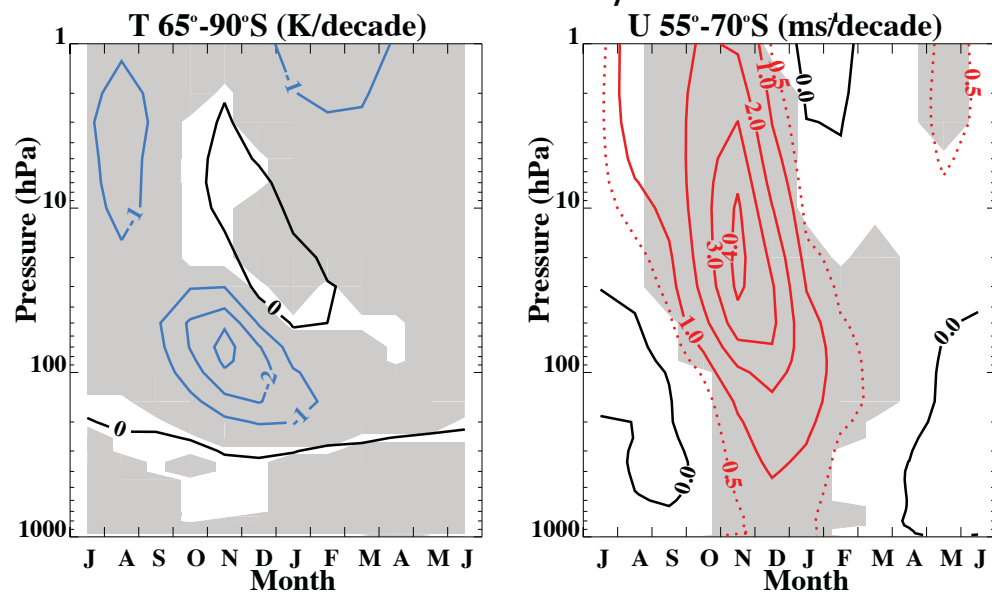


Prescribed ozone underestimates ozone depletion forcing

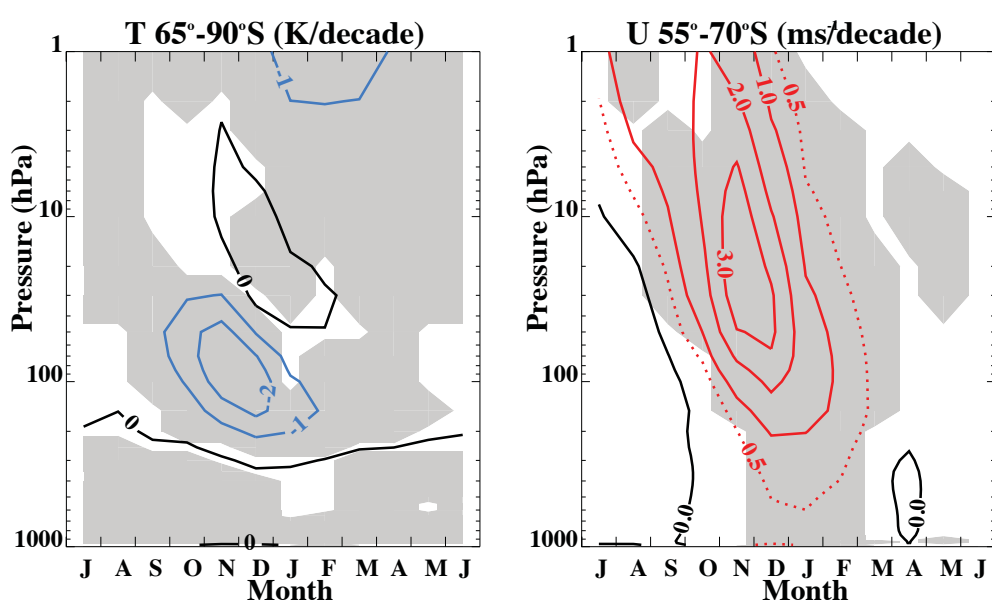


Prescribed ozone underestimates Antarctic climate change 1979-2010

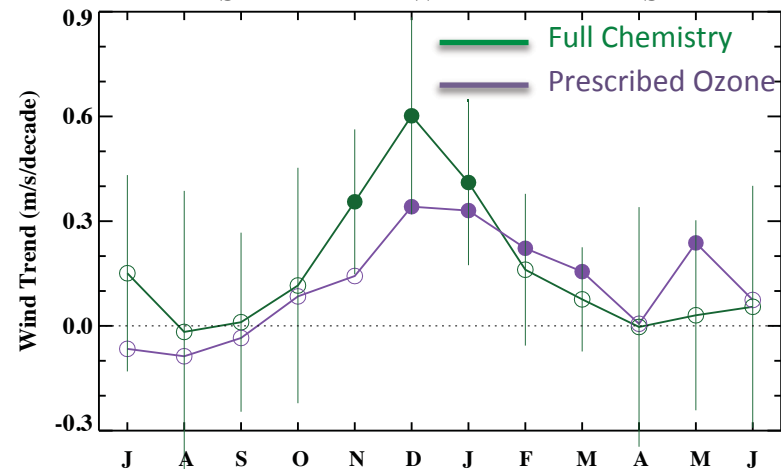
Full Chemistry



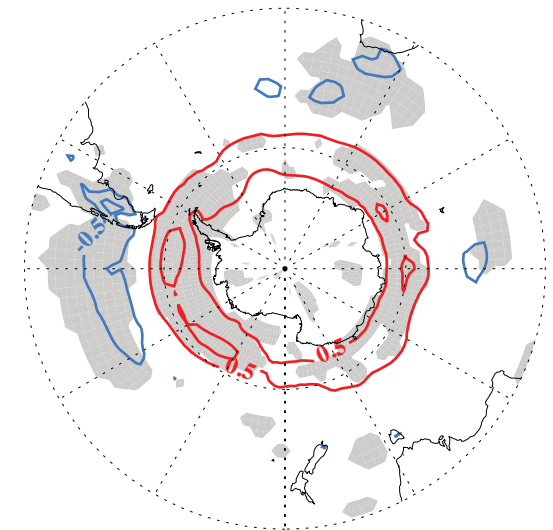
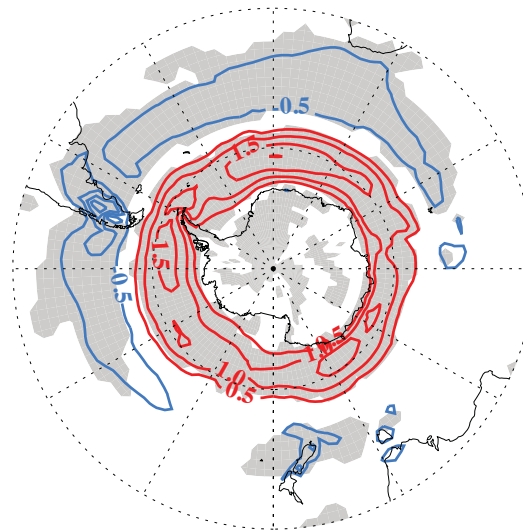
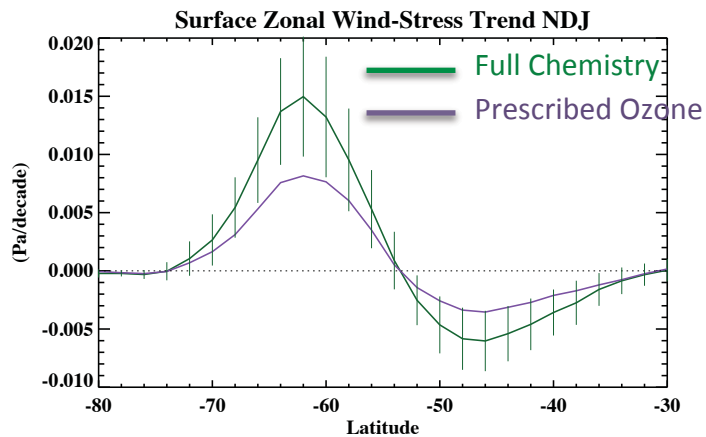
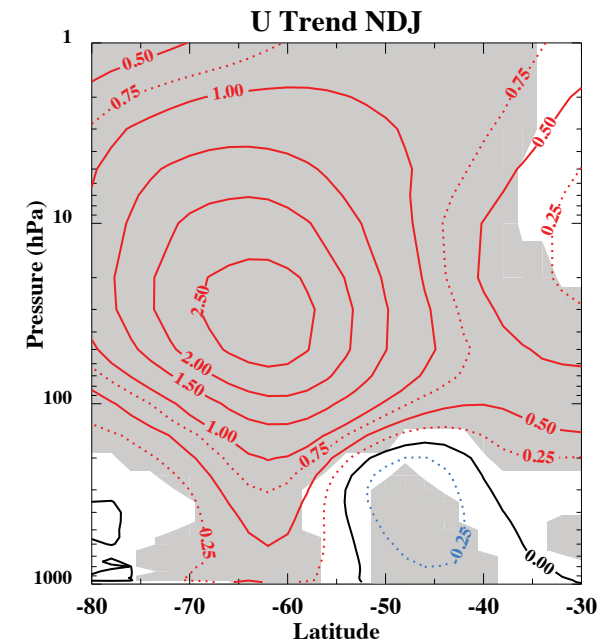
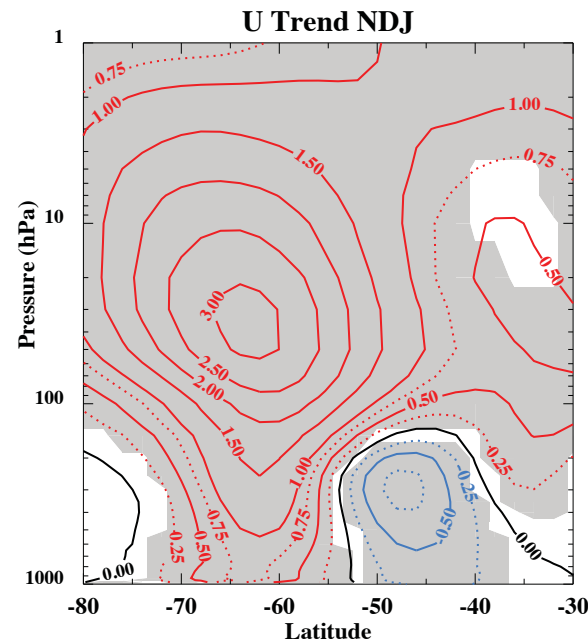
Prescribed Ozone



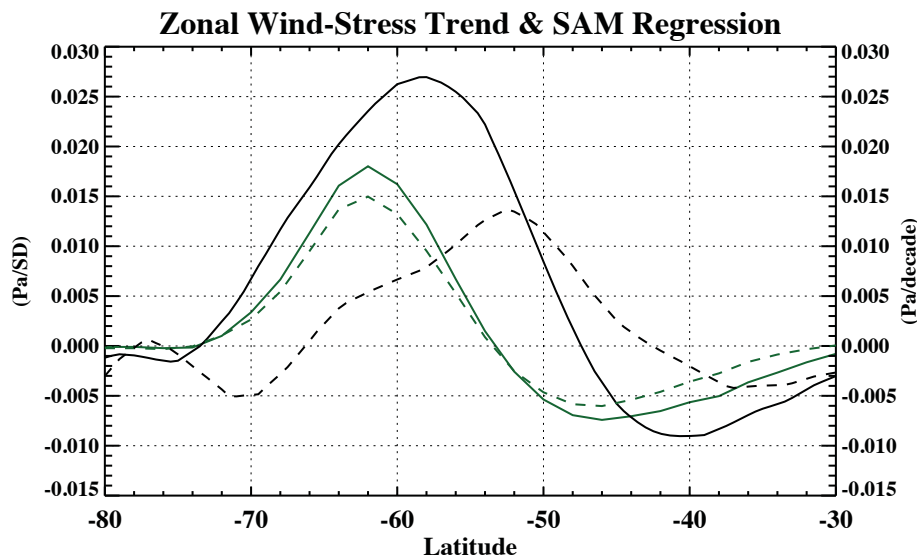
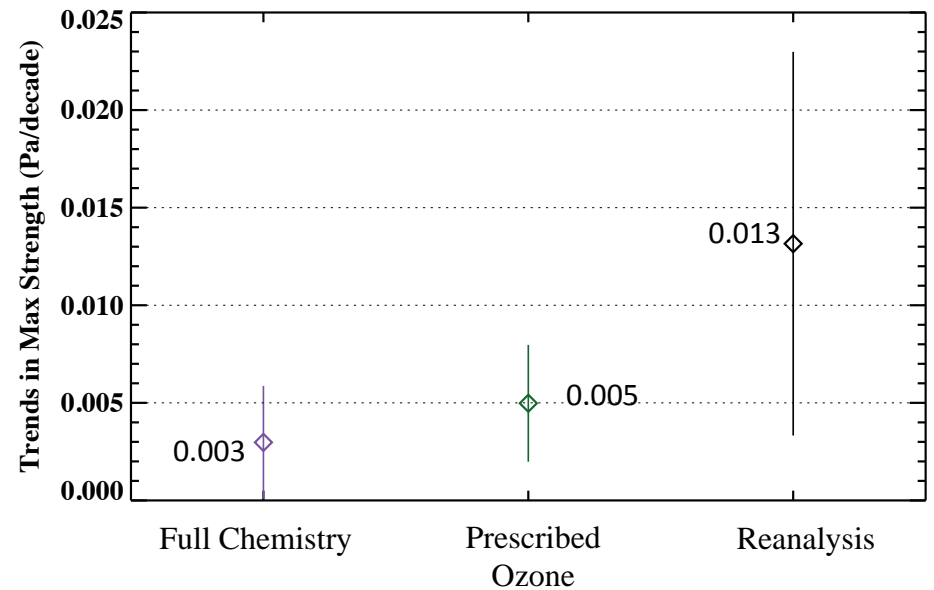
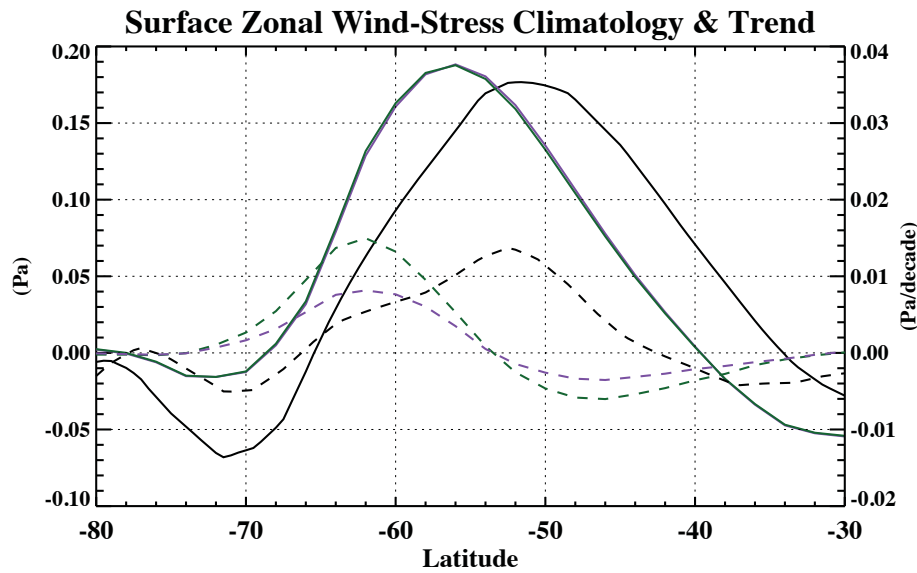
Surface Zonal Wind Trend 55-70S



Prescribed ozone underestimates Antarctic climate change



Wind-Stress Trends and the Southern Annular Mode

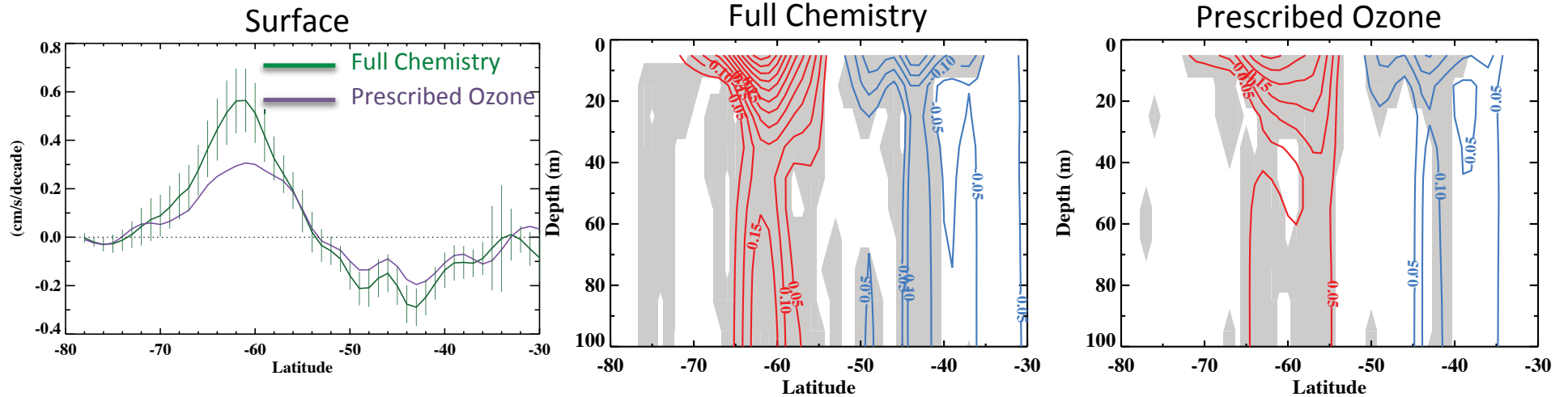


Full Chemistry

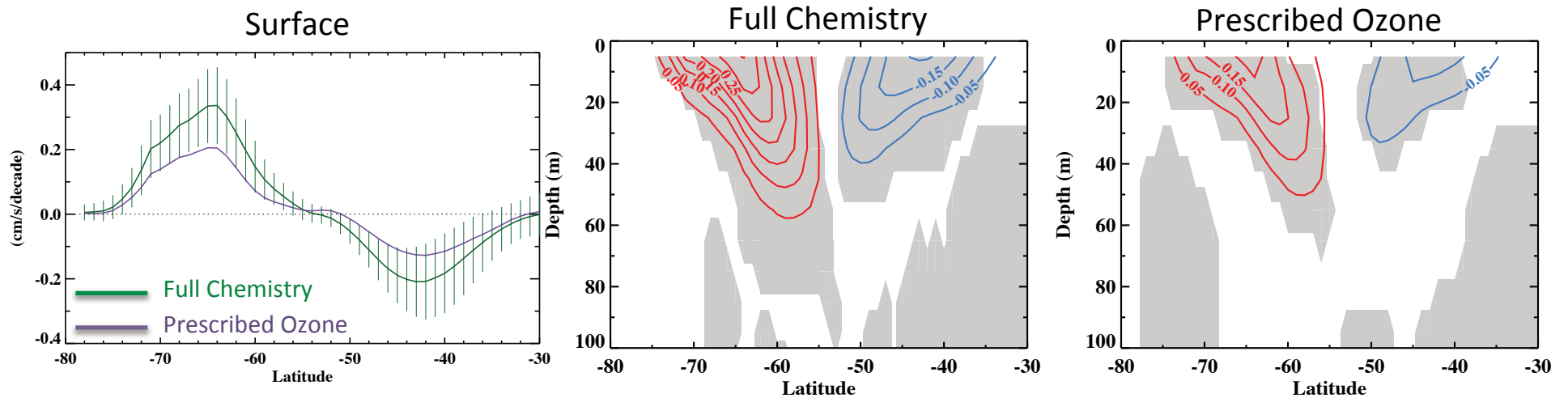
Prescribed Ozone

Southern Ocean Currents

Zonal Current Trends

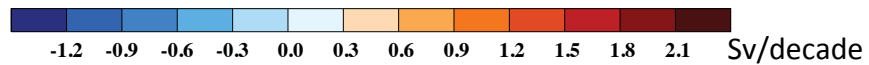
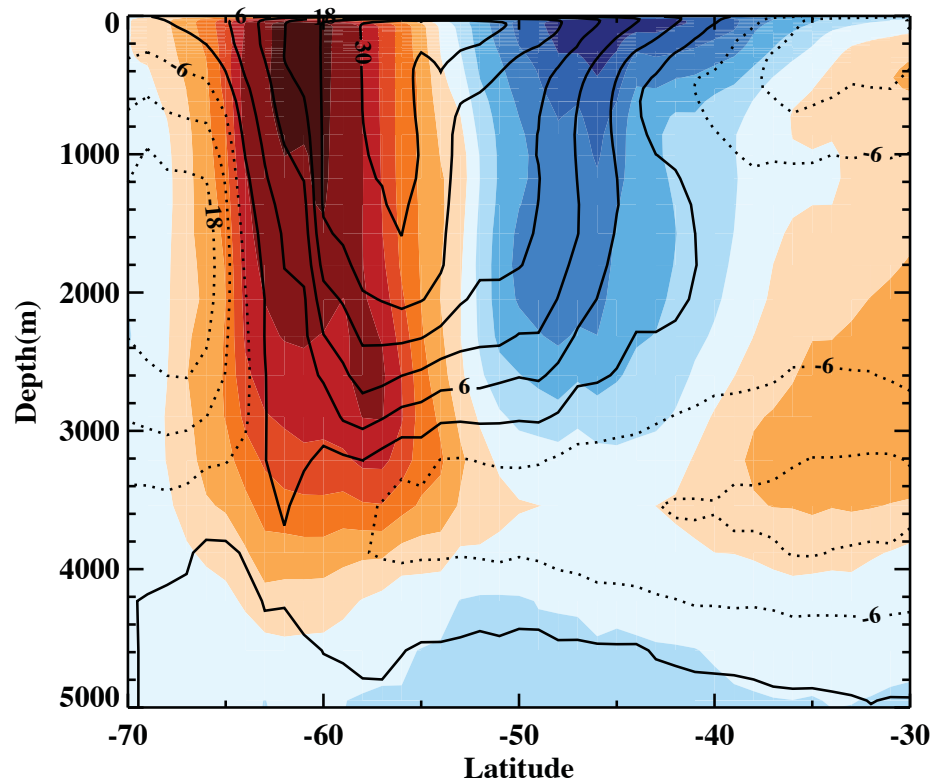


Meridional Current Trends

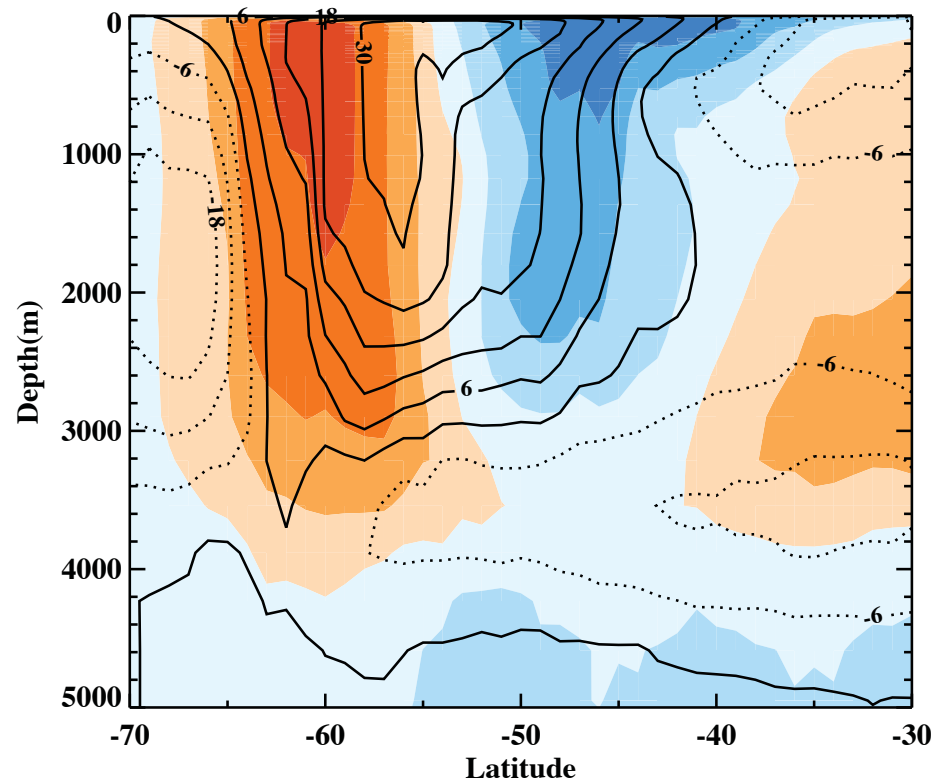


Meridional Overturning Circulation: Nov-Jan

Full Chemistry



Prescribed Ozone



Conclusions

- Compared to the interactive ozone simulations, the prescribed ozone simulations underestimate the strengthening of the SH westerly jet and surface wind-stress.
- Due to weak wind-stress changes, the prescribed ozone simulations have smaller trends in Southern Ocean circulation than the interactive ozone simulations.